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LLNL-TR-429551

Evaluation of Radiation Doses Due to Consumption of Contaminated Food Items and Calculation of Food Class-Specific Derived Intervention Levels

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April 28, 2010

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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1. Introduction:

This document evaluates the expected radiation dose due to the consumption of several specific food classes (dairy, meat, produce, etc.) contaminated with specific radionuclides, and relates concentration levels in food to the detection abilities of typical laboratory analysis/measurement methods. The attached charts present the limiting organ dose as a function of the radionuclide concentration in a particular food class, and allow the user to compare these concentrations and doses to typical analytical detection capabilities.

The expected radiation dose depends on several factors: the age of the individual; the radionuclide present in the food; the concentration of the radionuclide in the food; and the amount of food consumed. Food consumption rates for individuals of various ages were taken from the 1998 United States Food and Drug Administration (FDA) document, *Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies*. In that document, the FDA defines the Derived Intervention Level (DIL), which is the concentration of a particular radionuclide in food that if consumed could result in an individual receiving a radiation dose exceeding the Protection Action Guide (PAG) thresholds for intervention. This document also presents a modified, food class specific DIL, which is calculated using a somewhat modified version of the FDA's procedure. This document begins with an overview of the FDA's DIL calculation, followed by a description of the food class specific DIL calculations, and finally charts of the radiation dose per radioactivity concentration for several food class/radionuclide combinations.

2. FDA DIL Method:

As discussed in the introduction, the DIL corresponds to the concentration of a radionuclide in the food supply that, if consumed, could result in an individual receiving a radiation dose equal to a PAG. The DIL depends on several factors: the food intake rate; the dose conversion factor and the fraction of the food intake that is assumed to be contaminated. Below is the equation for the DIL presented in the FDA document:

$$\text{DIL (Bq/kg)} = \text{PAG (mSv)} \div (f \times \text{Food Intake (kg)} \times \text{DC (mSv/Bq)})$$

Where:

PAG: PAG = Protection Action Guide. The Protection Action Guide is the "projected dose commitment values to individuals in the general population that warrant protective action following a release of radioactive material[1]." The PAG values are 500 mrem committed effective dose equivalent or 5000 mrem committed dose equivalent to a tissue or organ.

f: f = Fraction of the food intake assumed to be contaminated. For most members of the general public, the fraction of food intake assumed to be contaminated is 10%. To account for sub-populations that may be more dependent on local food supplies, a conservative factor of three is applied, which results in f = 0.3 for most age groups. The exception is for infants, ages three months and one year. Due to their largely milk based diet, f = 1 for infants.

Food Intake: Food Intake = Quantity of food consumed over a defined period of time. Dietary intake values were derived by the FDA from a 1984 Environmental Protection Agency (EPA) document[2,3]. Specific annual consumption rates (kg/year) are listed for a variety of food classes. The rates are age dependent and have been derived for the age groups for which ICRP dose coefficients are available. All consumed food is included in the Food Intake factor, including tap water. The duration of consumption is one year for all but the short lived radionuclides I-131 and Ru-103, which have an assumed duration of consumption of 60 days and 280 days respectively.

DC: DC = Dose Coefficient; the radiation dose per unit of radioactivity ingested (mSv/Bq). Dose coefficients used in the FDA calculations were taken from ICRP document 56 for the various age groups. The integration period for this dose coefficient is 50 years.

3. Food Class Specific DILs:

The FDA's default DIL values are calculated assuming that all of the food classes consumed are equally contaminated. The FDA's method for DIL calculations is easily modified to permit the calculation of what might be called food class specific DILs. This paper evaluated food class-specific DILs that would (presumably) be applicable if only one food class was contaminated. For example, if the contamination is limited to the milk supply, what concentration of a particular radionuclide in milk warrants intervention?

The charts that follow were generated using the FDA's DIL method with the following exceptions:

- The annual consumption (Food Intake) is limited to the specific food item that is assumed to be contaminated.
- 100% of each specific food item is assumed to be contaminated, rather than 30% of all food consumed.
- The ICRP 72 dose coefficients are used, replacing the ICRP 56 dose coefficients used in the FDA's DIL calculations. The ICRP 72 dose coefficients are based on updated biokinetic models for the various materials and are considered to be more realistic than the ICRP 56 dose coefficients. The ICRP 72 dose coefficients were taken from the ORNL Radiological Toolbox code. [4]

Food specific DILs were calculated for six radionuclides in four food classes:

- Pu-239 in fish
- Th-230 in beverage, not including tap water
- Cs-137 in beverage, not including tap water
- Am-241 in beverage, not including tap water
- Am-241 on the surface of produce
- Sr-90 on the surface of produce
- Cs-137 on the surface of produce
- I-131 in milk

For each food class/radionuclide combination, the committed effective dose and the committed equivalent dose to the organ of concern were calculated for each of the ICRP 72 age groups: 3 months; 1 year; 5 years; 10 years; 15 years; and adult. The age group whose radiation dose per radioactivity concentration was the highest fraction of the PAG, (i.e. the age group that reaches the PAG with the lowest concentration of radioactivity per gram of food) is considered the age group representing the *limiting dose*.

In the attached charts the limiting dose is plotted against the concentration of the applicable radionuclide for concentrations ranging from below the expected detection limit to above the food specific DIL. In addition to the dose resulting from one year of consumption of contaminated food, the dose from 30 days of consumption is plotted. The expected detection limits (minimum detectable concentrations, MDC), when using standard counting methods appropriate for each radionuclide, are also shown on each chart. The charts show that standard counting methods are nearly always adequate to detect concentrations at the food specific DIL, and in many cases they are able to detect concentrations orders of magnitude lower.

4. Acknowledgements

Thanks to Charley Yu for his review and feedback on the draft chart format.

References

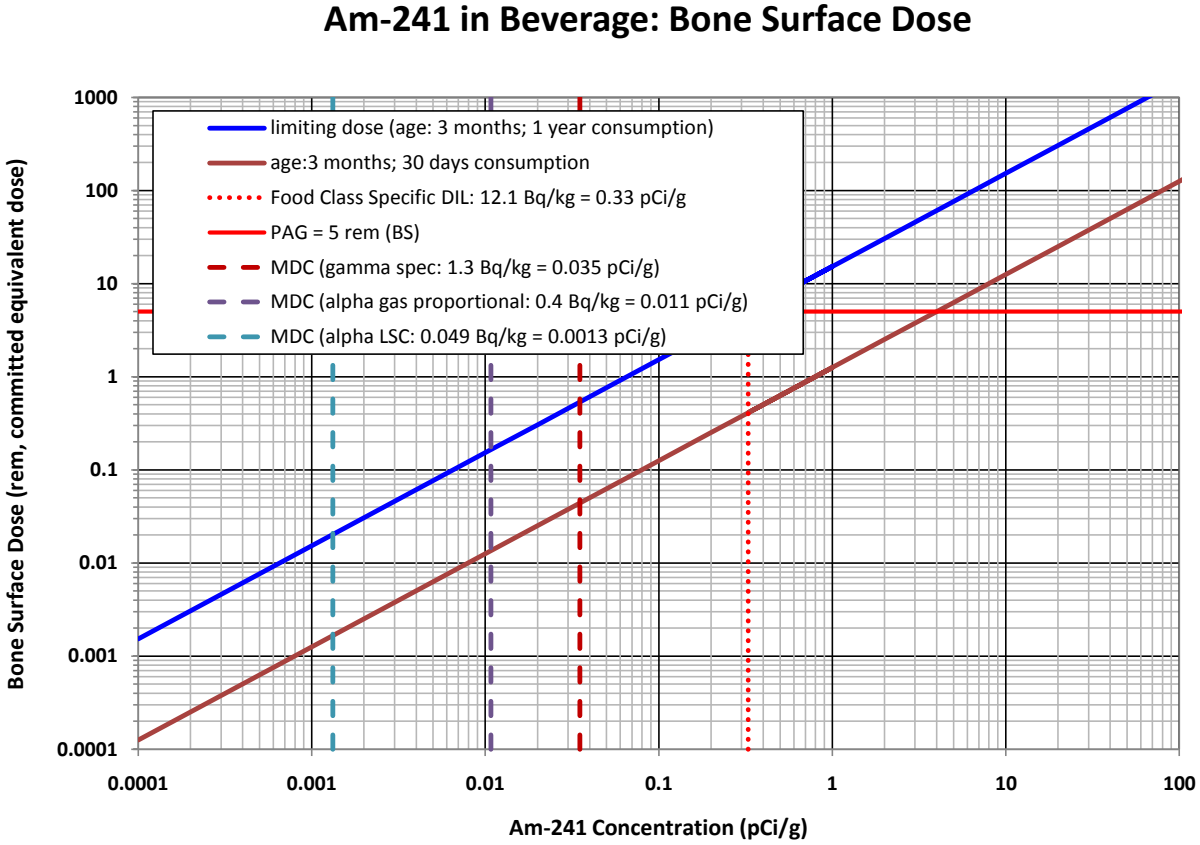
[1] (FDA 1998) Food and Drug Administration. Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies.

[2] (EPA l984a) Environmental Protection Agency. An Estimation of the Daily Food Intake Based on Data from the 1977-1978 USDA Nationwide Food Consumption Survey. Office of Radiation Programs. Washington, D.C.: EPA 520/1-84-015; 1984.

[3] (EPA 1984b) Environmental Protection Agency. An Estimation of the Daily Average Food Intake by Age and Sex for Use in Assessing the Radionuclide Intake of Individuals in the General Population. Office of Radiation Programs. Washington, D.C.: EPA 520/1-84-021; 1984.

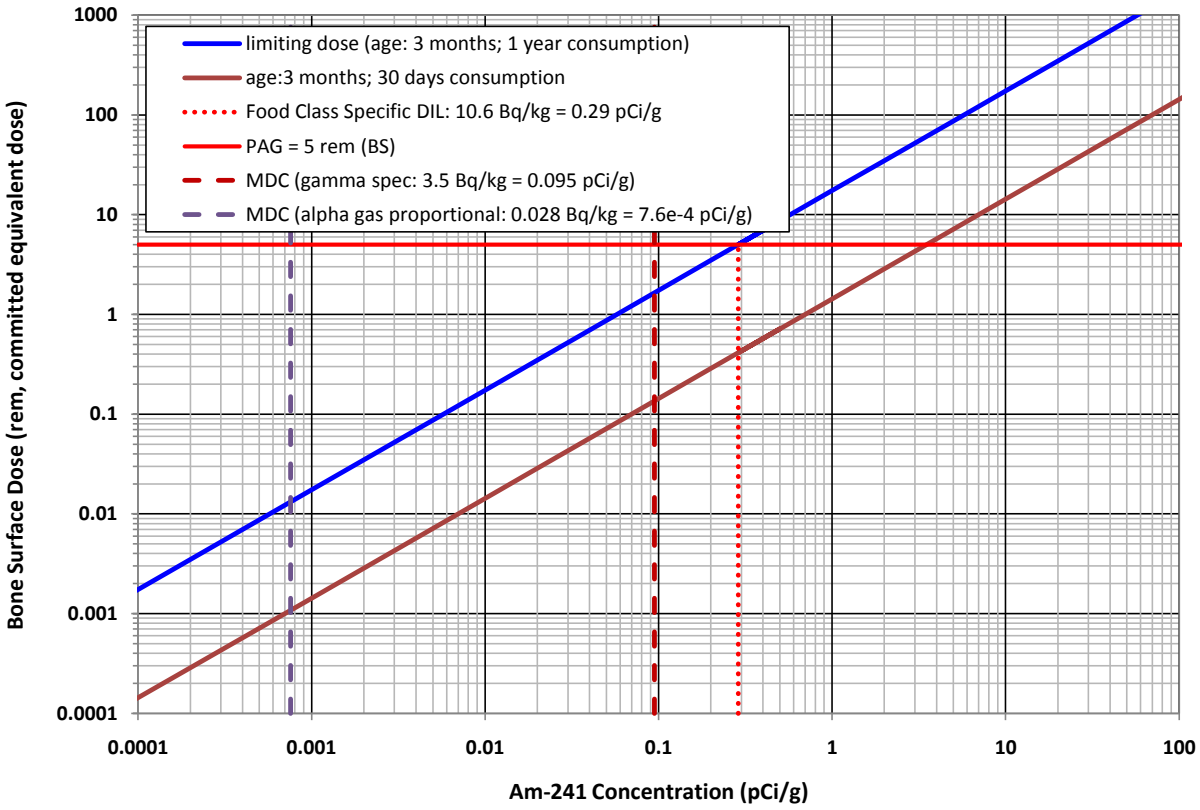
[4] Eckerman, K.F.; Sjoreen, A.L., *Rad Toolbox* software V2.0.0, 2007

5. Charts



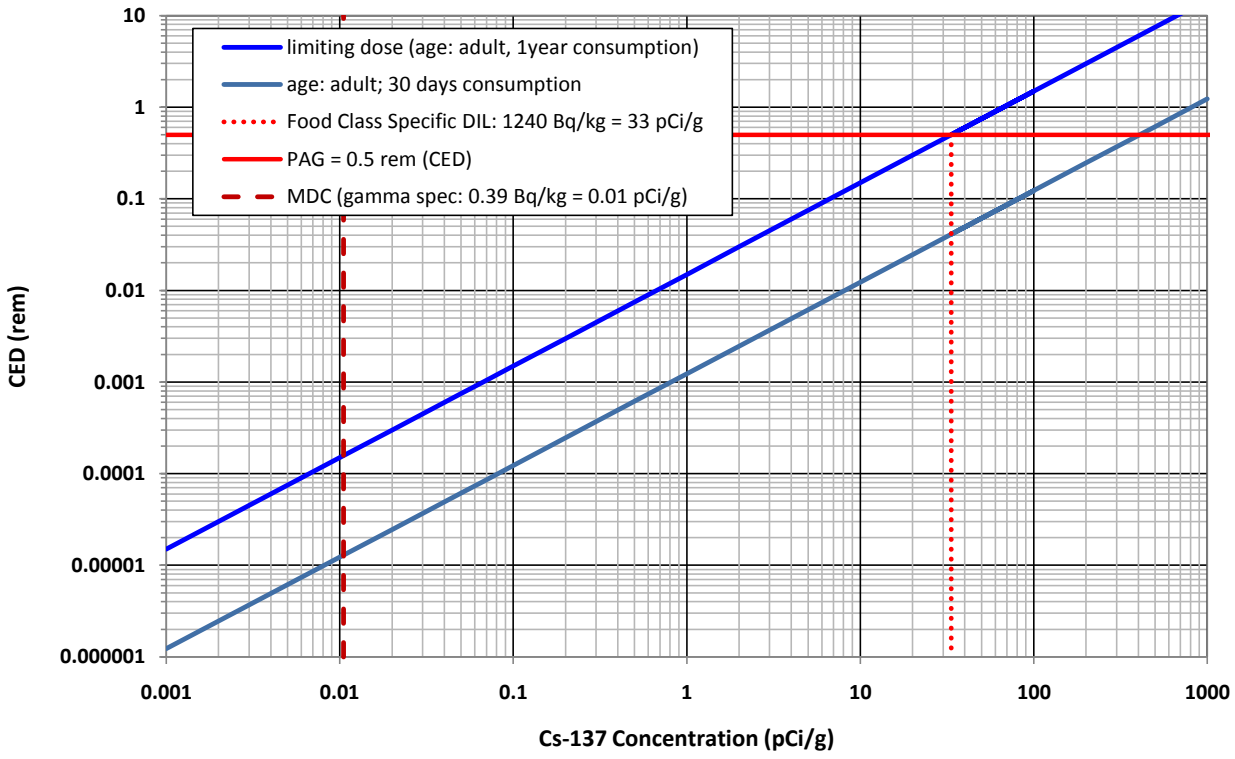
Am-241 in Beverage: The limiting dose is the committed equivalent dose to the bone surface of an infant, age 3 months. The dose and the Food Class Specific DIL is calculated following the FDA's methodology for consumption of contaminated food, with the following exceptions: 1) annual consumption is of beverages, not including tap water, only; 2) 100% of the beverages (again, not including tap water) consumed is assumed to be contaminated; 3) the ICRP 72 dose conversion factors are used.

Am-241 on Surface of Produce: Bone Surface Dose



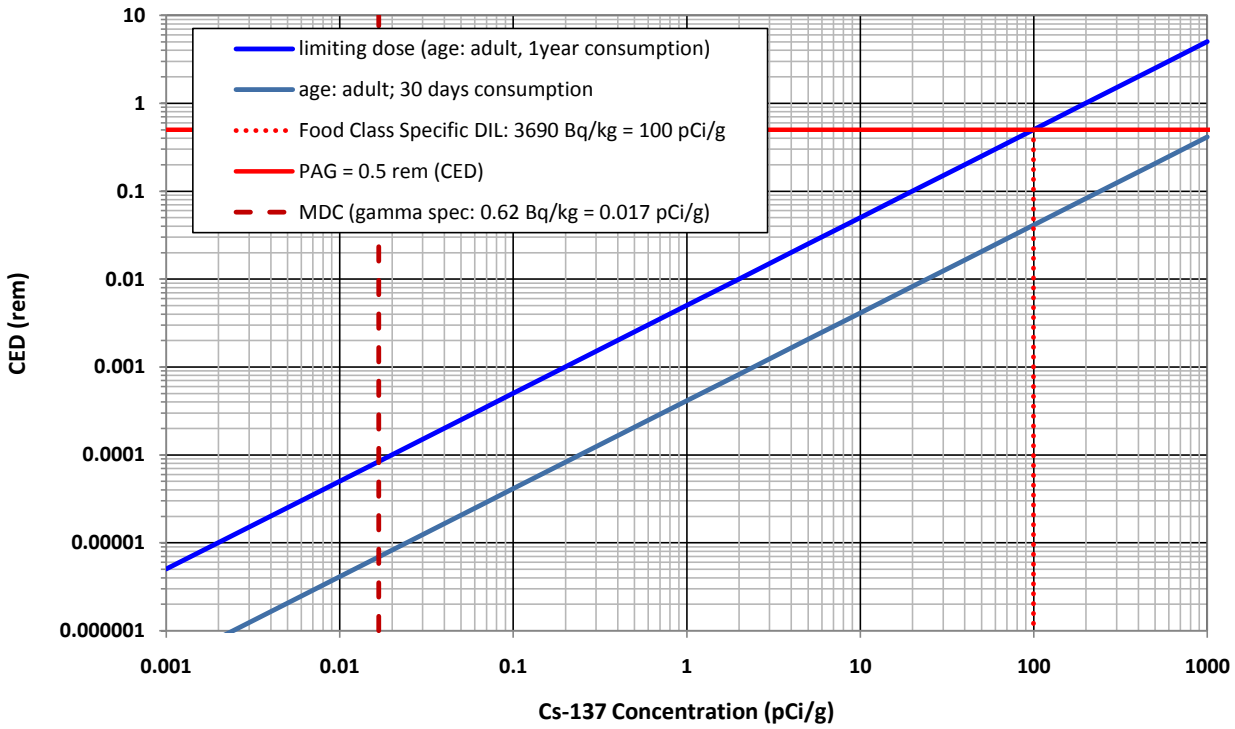
Am-241 on the Suface of Produce: The limiting dose is the committed equivalent dose to the bone surface of an infant, age 3 months. The dose and the Food Class Specific DIL is calculated following the FDA's methodology for consumption of contaminated food, with the following exceptions: 1) annual consumption is of produce only; 2) 100% of the produce consumed is assumed to be contaminated; 3) the ICRP 72 dose conversion factors are used.

Cs-137 in Beverage: Committed Effective Dose

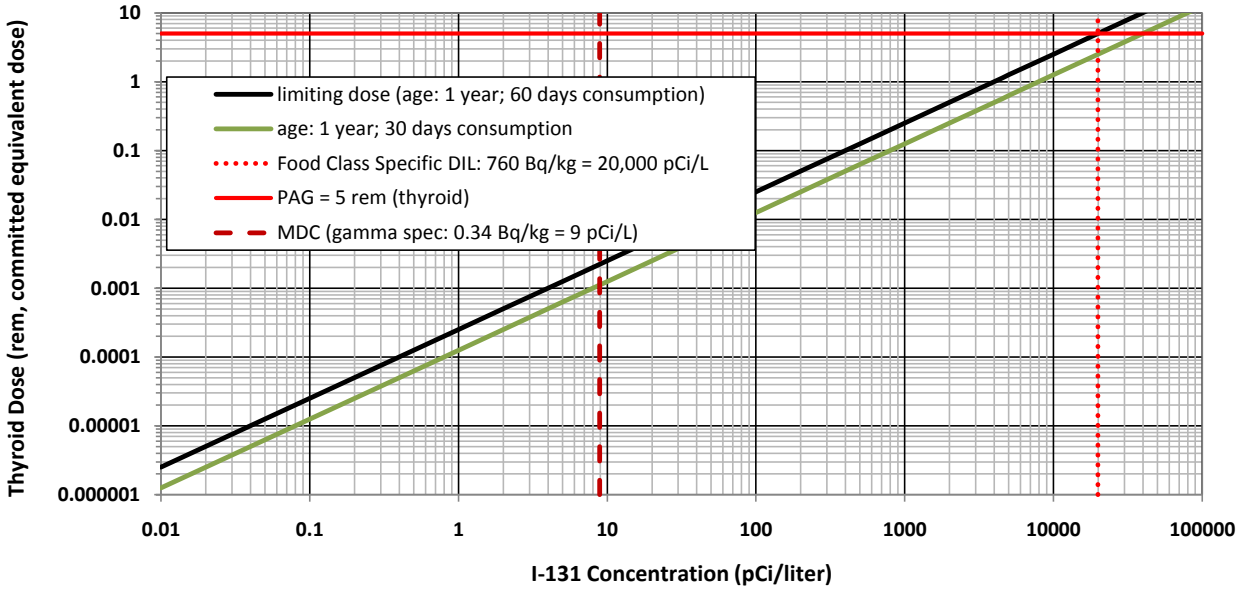


Cs-137 in Beverage: The limiting dose is the committed effective dose to an adult. The dose and the Food Class Specific DIL is calculated following the FDA's methodology for consumption of contaminated food, with the following exceptions: 1) annual consumption is of beverages, not including tap water, only; 2) 100% of the beverages (again, not including tap water) consumed is assumed to be contaminated; 3) the ICRP 72 dose conversion factors are used.

Cs-137 on Surface of Produce: Committed Effective Dose

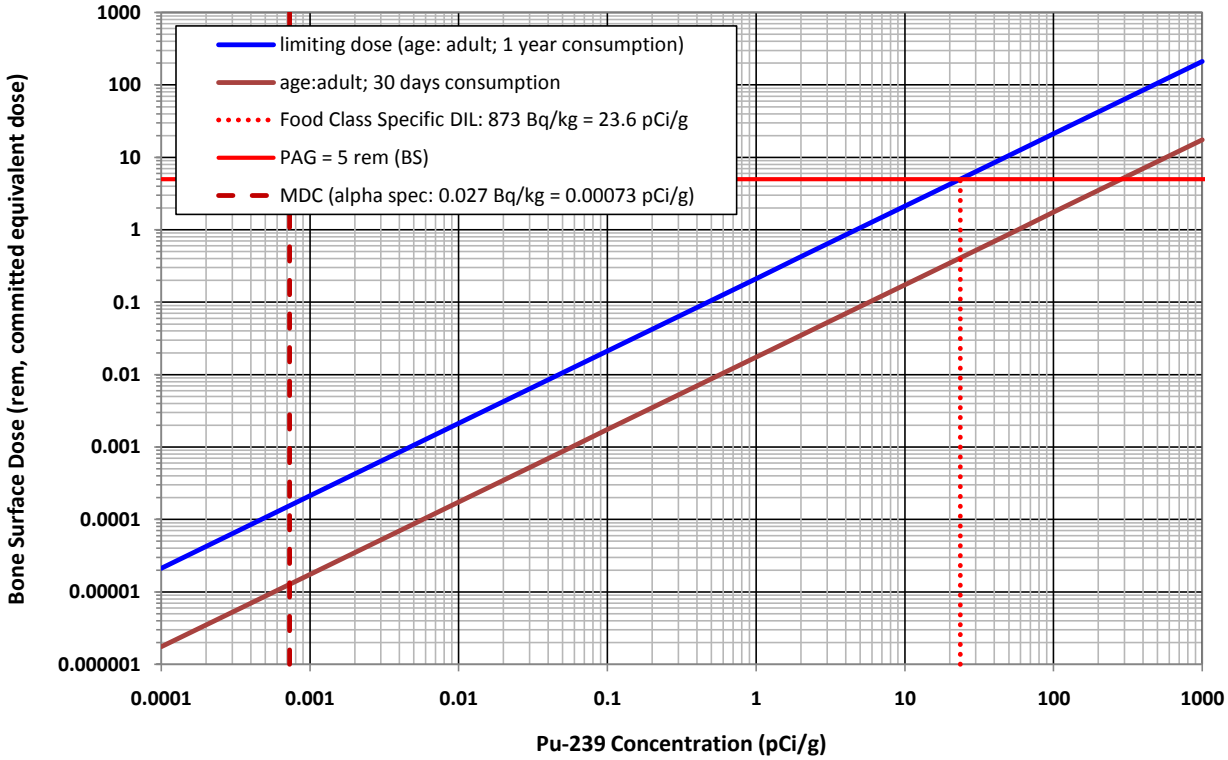


Cs-137 on the Suface of Produce: The limiting dose is the committed effective dose to an adult. The dose and the Food Class Specific DIL is calculated following the FDA's methodology for consumption of contaminated food, with the following exceptions: 1) annual consumption is of produce only; 2) 100% of the produce consumed is assumed to be contaminated; 3) the ICRP 72 dose conversion factors are used.



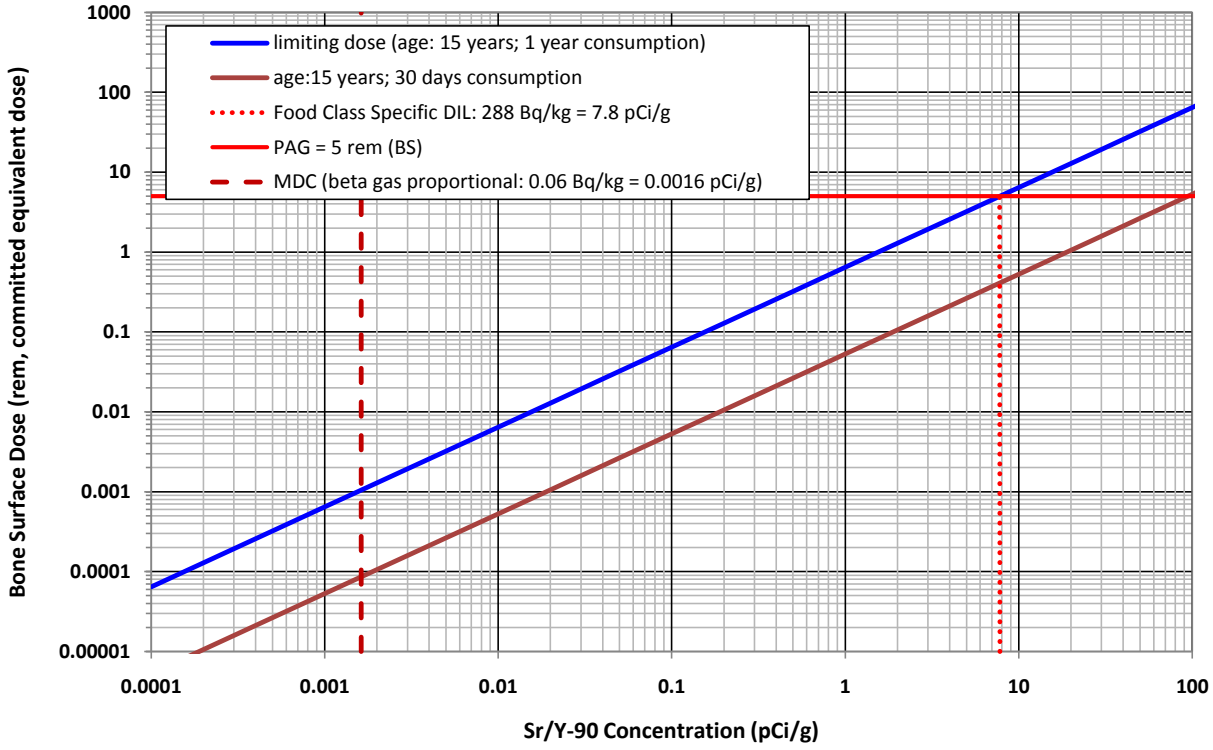
I-131 in Milk: The limiting dose is the committed equivalent dose to the thyroid of an infant, age 1 year. The dose and the Food Class Specific DIL is calculated following the FDA's methodology for consumption of contaminated food, but using the ICRP 72 dose conversion factors.

Pu-239 in Fish: Bone Surface Dose



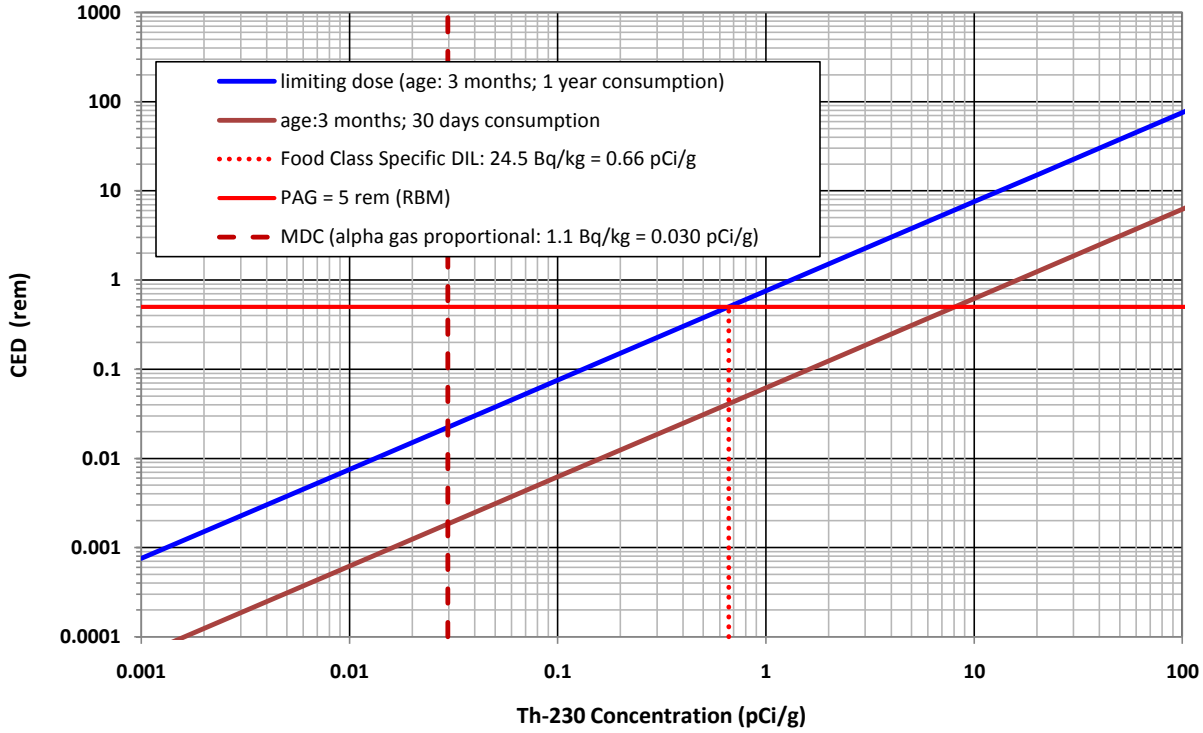
Pu-239 in Fish: The limiting dose is the committed equivalent dose to the bone surface of an adult. The dose and the Food Class Specific DIL is calculated following the FDA's methodology for consumption of contaminated food, with the following exceptions: 1) annual consumption is of fish only; 2) 100% of fish consumed is assumed to be contaminated; 3) the ICRP 72 dose conversion factors are used.

Sr-90 on Surface of Produce: Bone Surface Dose



Sr-90 on the Suface of Produce: The limiting dose is the committed equivalent dose to a child, age 15 years. The dose and the Food Class Specific DIL is calculated following the FDA's methodology for consumption of contaminated food, with the following exceptions: 1) annual consumption is of produce only; 2) 100% of the produce consumed is assumed to be contaminated; 3) the ICRP 72 dose conversion factors are used.

Th-230 in Beverage: Red Bone Marrow Dose



Th-230 in Beverage: The limiting dose is the committed equivalent dose to the red bone marrow of an infant, age 3 months. The dose and the Food Class Specific DIL is calculated following the FDA's methodology for consumption of contaminated food, with the following exceptions: 1) annual consumption is of beverages, not including tap water, only; 2) 100% of the beverages (again, not including tap water) consumed is assumed to be contaminated; 3) the ICRP 72 dose conversion factors are used.